

WHAT IS CLAIMED IS:

1. A clock and data recovery circuit, comprising:
  - (a) a multi-phase voltage-controlled oscillator (VCO) for accepting a control signal and for changing a frequency of a clock signal output from the VCO in response thereto, wherein the voltage-controlled oscillator outputs a plurality of phases of the clock signal;
  - (b) a phase detector (PD) for sampling an input data signal using the clock signal received from the voltage-controlled oscillator and generating a plurality of data output signals in response thereto, wherein each of the data output signals detects an edge or transition in the input data signal and whether the edge or transition is early or late with respect to its corresponding clock signal phase;
  - (c) a Voltage-to-Current (V/I) Converter for converting the data output signals from the phase detector to a control current; and
  - (d) a loop filter (LPF) for integrating the control voltage from the Voltage-to-Current Converter and for outputting the control signal to the voltage-controlled oscillator in response thereto.
2. The clock and data recovery circuit of claim 1, wherein the circuit accepts a single input data signal, and re-times and de-multiplexes the input data signal to a plurality of output data signals.
3. The clock and data recovery circuit of claim 1, wherein the phase detector uses half-quadrature phases of the clock signal provided by the voltage-controlled oscillator to sample the input data signal, thereby detecting the edges or transitions in the input data signal, and determining whether the clock signal is early or late.
4. The clock and data recovery circuit of claim 1, wherein the phase detector employs a plurality of flip-flops to strobe the input data signal at intervals based on the plurality of phases of the clock signal received from the voltage-controlled oscillator.

5. The clock and data recovery circuit of claim 1, wherein the phase detector compares every two adjacent or consecutive samples stored by two adjacent or consecutive flip-flops by means of an associated XOR gate, which generates a net output current if the two adjacent or consecutive samples are unequal, thereby indicating that an edge or transition has occurred in the input data signal.

6. The clock and data recovery circuit of claim 1, wherein the phase detector uses both leading and trailing edges of the phases of the clock signal to sample the input data signal, in order to detect the edges or transitions in the input data signal.

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7. The clock and data recovery circuit of claim 1, wherein the voltage-controlled oscillator sustains a phase separation of  $180^\circ$  at diagonally-opposite nodes, providing  $45^\circ$  phase steps in between for the clock signal.

8. The clock and data recovery circuit of claim 1, wherein the voltage-controlled oscillator's oscillation frequency is uniquely given by a travel time of a wave around a loop.

9. The clock and data recovery circuit of claim 1, wherein inductor elements of the voltage-controlled oscillator are grouped into differential structures and  $-G_m$  cells are placed in close proximity to the nodes of the voltage-controlled oscillator.

10. The clock and data recovery circuit of claim 1, wherein each differential port of the voltage-controlled oscillator is buffered by an inductively-loaded differential pair of switches.

30

11. A method of clock and data recovery, comprising:

(a) accepting a control signal into a multi-phase voltage-controlled oscillator (VCO) and changing a frequency of a clock signal output from the VCO in response thereto, wherein the voltage-controlled oscillator outputs a plurality of phases of the clock signal;

(b) sampling an input data signal at a phase detector (PD) using the clock signal received from the voltage-controlled oscillator and generating a plurality of data output signals in response thereto, wherein each of the data output signals detects an edge or transition in the input data signal and whether the edge or transition is early or late with respect to its corresponding clock signal phase;

(c) converting the data output signals from the phase detector to a control current at a Voltage-to-Current (V/I) Converter; and

(d) integrating the control voltage from the Voltage-to-Current Converter at a loop filter (LPF) and outputting the control signal to the voltage-controlled oscillator in response thereto.

12. The method of clock and data recovery of claim 11, further comprising accepting a single input data signal, and re-timing and de-multiplexing the input data signal to a plurality of output data signals.

13. The method of clock and data recovery of claim 11, wherein the phase detector uses half-quadrature phases of the clock signal provided by the voltage-controlled oscillator to sample the input data signal, thereby detecting the edges or transitions in the input data signal, and determining whether the clock signal is early or late.

14. The method of clock and data recovery of claim 11, wherein the phase detector employs a plurality of flip-flops to strobe the input data signal at intervals based on the plurality of phases of the clock signal received from the voltage-controlled oscillator.

15. The method of clock and data recovery of claim 11, wherein the phase detector compares every two adjacent or consecutive samples stored by two adjacent or consecutive flip-flops by means of an associated XOR gate, which generates a net output current if the two adjacent or consecutive samples are unequal, thereby indicating that an edge or transition has occurred in the input data signal.

16. The method of clock and data recovery of claim 11, wherein the phase detector uses both leading and trailing edges of the phases of the clock signal to sample the input data signal, in order to detect the edges or transitions in the input data signal.

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17. The method of clock and data recovery of claim 11, wherein the voltage-controlled oscillator sustains a phase separation of  $180^\circ$  at diagonally-opposite nodes, providing  $45^\circ$  phase steps in between for the clock signal.

18. The method of clock and data recovery of claim 11, wherein the voltage-controlled oscillator's oscillation frequency is uniquely given by a travel time of a wave around a loop.

19. The method of clock and data recovery of claim 11, wherein inductor elements of the voltage-controlled oscillator are grouped into differential structures and  $G_m$  cells are placed in close proximity to the nodes of the voltage-controlled oscillator.

20. The method of clock and data recovery of claim 11, wherein each differential port of the voltage-controlled oscillator is buffered by an inductively-loaded differential pair of switches.

25